

GM cotton for Africa

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Abstract: Cotton is the most important cash crop for smallholders in many countries of Sub-Saharan Africa (SSA). Although GM cotton has been grown in South Africa for more than 10 years, most of the other SSA countries are only now enacting the biosafety legislation, with the supporting biotechnology policy, to enable them to acquire GM cotton technology from the biotechnology companies that hold the intellectual property rights. Burkina Faso, now the largest cotton producer in SSA, will be the first to make GM cotton available to smallholders. GM cotton is being promoted in the rest of SSA on the basis of its apparent success in improving the profitability of cotton growing as a smallholder enterprise in South Africa, India and China. With several other African countries soon to follow Burkina Faso in adopting GM cotton technology, this paper examines the potential benefits for Africa in the light of evidence from smallholder adoption elsewhere in the world.

Keywords: GM cotton; Bt cotton; Sub-Saharan Africa

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As Burkina Faso (BF) becomes the first country in Sub-Saharan Africa (SSA) (except for the Republic of South Africa [RSA]), to embark upon commercial planting of genetically modified (GM) cotton, it seems appropriate to discuss prospects for the success of this venture in BF and other African countries that have already started, or will soon embark upon confined testing of GM cotton varieties. The African countries that have the biosafety legislation and corresponding policy in place to obtain the intellectual property rights (IPR) from the holders (mainly Monsanto) and to undertake confined field testing are: Benin, Cameroon, Mauritius, Tanzania, Kenya, Uganda, Namibia, Zimbabwe, Malawi and Zambia (UNEP, 2006). Thirty-six African countries are participating in the UNEP Global Environment Facility initiative to assist in the development of a national biosafety policy and law. The debate is no longer about whether or not African countries should adopt GM cotton, it is now about how to make effective use of the technology to improve the profitability of smallholder cotton.

GM cotton in the present context refers to cotton that has been transformed with a gene from the bacterium *Bacillus thuringiensis* (Bt), which controls the production of an endotoxin and allows its expression within the plant. Bt toxin is active against certain insect pests, primarily the Lepidopteran bollworms. Other GM cotton varieties have been commercially adopted that carry genes for herbicide tolerance, enabling cotton fields to be treated with herbicide after the crop has emerged. Those varieties with

resistance to the herbicide glyphosate, which is marketed as 'Roundup', are known as 'Roundup-ready' or RR. Although RR cotton varieties are widely grown elsewhere, African countries have opted first for the Bt technology. Since they were first planted commercially in the USA in 1994, GM cottons have become widely grown throughout the world. The largest areas under GM cotton are to be found in the USA, Argentina, Brazil, China and India, but significant areas of GM varieties have been planted in a number of other countries (Table 1).

Cotton in rural livelihoods

Cotton growing is an important livelihood strategy for large numbers of rural households in SSA. The crop is grown mainly on small family farms with typically 0.5–4 ha under cotton. Burkina Faso has become the largest cotton-producing country in Africa, where around three million people are involved in growing the crop. Cotton makes a significant contribution to household income and export earnings in a number of other African countries (Table 2).

Cotton is able to provide an income to smallholders living in drier areas, where there may be few, if any, alternative cash crops. However, even in more favourable environments, cotton growing often provides poor returns on investment in land and labour. Cotton is also a demanding crop in terms of crop husbandry and pest management. As a consequence, average yields in most

Table 1. Countries growing GM cotton in 2007/08.

Country	Area (million ha)
Argentina	19.1
Australia	0.1
Brazil	15.0
Burkina Faso (seed production from June 2008)	–
China	3.8
Colombia	0.1
India	6.2
Mexico	0.1
South Africa	1.8
USA	57.7

Source: James (2007), except Burkina Faso (see ICTSD, 2008).

Table 2. Leading cotton producers in Africa.

Country	Production (tonnes of lint)
Burkina Faso	290,000
Mali	160,000
Nigeria	152,000
Côte d'Ivoire	114,000
Sudan	105,740
Tanzania	99,000
Chad	86,000
Benin	78,000
Zimbabwe	72,000
Cameroon	58,000
Togo	52,000
Zambia	42,500
Uganda	37,000
Mozambique	25,000
Ethiopia	22,000
Malawi	19,000
Senegal	19,000

Source: FAOStat, 2006.

SSA countries are well below the yield potential of current varieties under rainfed conditions. In eastern and southern Africa, yields of 500–700 kg/ha of seed cotton are typical for varieties with a yield potential closer to 3,000 kg/ha. Under irrigation, cotton farmers in developed countries can obtain yields of 4,000–5,000 kg/ha. While the world market price for cotton remains low and where there are markets for other crops, few farmers are willing to grow cotton. For those relying on family labour to cultivate their cotton, a yield of 600 kg/ha of seed cotton would probably not cover the input cost, if that labour was included in the calculation of net cost benefit. Under these circumstances it is not surprising that national annual cotton production varies greatly from year to year and, although weather plays an important part in the variation, the farm gate price per kg of seed cotton in the previous season has a strong influence on the area planted.

In Burkina Faso and other countries in French-speaking West Africa, the post-colonial history of developments in

the cotton sector has been different from that of eastern and southern Africa. Average yields tend to be higher in West Africa as a result of better crop management, by retaining efficient vertically integrated production to market chains and by effective input and technical services. The key to getting the best returns for the farmer from cotton growing is the establishment of effective and sustainable mechanisms for the delivery of credit for input purchase, combined with easy access to the correct inputs, supported by technical services to ensure the farmer has the knowledge to make the best use of those inputs. The picture in eastern and southern Africa is more varied, depending on how cooperation and competition have been balanced in the cotton sector, since the structural adjustment era saw cotton ginning and marketing pass to the private sector from state and parastatal organizations. At the risk of oversimplifying, it has become a choice between two situations: the first in which there are few ginning companies that do not compete for seed cotton and are therefore willing to invest in cotton production through input and technical support to their growers. The second involves intense competition between many ginning companies, unwilling to invest in input credit because the risk is too great that the farmer will accept credit, but then sell the crop to another company for a higher price and/or avoid repayment (Poulton *et al.*, 2004).

What is driving the demand for GM cotton in Africa?

It would probably be fair to say that in Africa, it is the 'yield gap', that is, the difference between yield potential and actual yield, which is creating the demand for GM cotton. This is different from India, Australia and the USA, for instance, where the driver was excessive pesticide use and the development of pesticide resistance in target insect populations. It is doubtful whether pesticide use is sufficiently great in African smallholder systems for this alone to create the demand for GM cotton among smallholders. Nevertheless, the need for high expenditure on insecticide is perceived as a major disincentive to grow cotton among those farmers who follow recommended practice with respect to insecticide sprays (usually 4–6 at regular intervals). African cotton farmers, like any other farmers, seek ways to increase the profitability of their enterprises. One way to do this is to decrease the use of insecticide, which has been estimated in Kenya to account for 50% of all input expenditure in cotton production.

For Ministries of Agriculture in countries that rely on cotton for a substantial part of their export earnings, the challenge is how to persuade enough households to continue to grow cotton, when it is such a difficult and unrewarding enterprise. Governments therefore see *Bt* technology as an opportunity to increase their country's cotton production, by offering farmers a variety that they expect will produce more yield for less expenditure on pesticides. They are only too eager to enter into deals with Monsanto to gain access to this technology, which, according to so many sources, has been highly successful elsewhere in the world. This of course is a very enticing message for farmers, and they are unlikely to oppose a

technology that, for apparently no effort on their part, promises to relieve them of the expense, drudgery and health risks associated with spraying for insect control.

The question is, can that promise be delivered? The answer is not a simple 'yes' or 'no', as there are many factors that influence the profitability of cotton growing, but the promise is probably being exaggerated and the potential for GM cotton to improve the profitability of cotton growing for millions of smallholders in Africa is being jeopardized by that exaggeration. A more realistic appraisal and careful promotion of *Bt* cotton technology is more likely to result in successful adoption.

Bt is not a yield-enhancing technology; it is a crop protection technology. All crop protection interventions protect from destruction by pests the yield that has been produced through correct crop management. Under conditions of adequate soil fertility and rainfall, the closer crop management practice is to the optimum, the closer the yield will be to the potential for that variety, and in turn, the greater the need to protect from pests the investment contained in the crop yield. This is a basic principle, but seems to be overlooked in the debate on the appropriateness of *Bt* cotton for African smallholders. The low yields obtained reflect the reality that crop management among most cotton smallholders in Africa is far from best practice. A farmer who is getting only 600 kg/ha from the current varieties due to poor crop management is unlikely to obtain a significantly higher yield from a *Bt* variety, but he will have paid considerably more for the seed.

In the hypothetical absence of insect pests, introduced *Bt* varieties are unlikely to be higher-yielding than conventional African cotton varieties. Most countries in SSA grow varieties that have been selected for those environments, and many of the larger cotton-growing countries have their own breeding programmes. It would be surprising if varieties developed in the USA had a higher yield potential under African conditions. Indeterminacy for instance, which is a characteristic of African Upland cotton, provides a buffer against crop loss because new flowers will set to replace the bolls that have been lost. American varieties have been selected for determinacy, which is more suitable for machine harvesting. African varieties have been selected for increased density of leaf hairs, which confers resistance to the jassid bug (*Empoasca* spp.). Similar leafhoppers are not significant pests in the USA, where cotton varieties tend to have relatively hairless leaves. Further down the line, Monsanto (or another biotech company) may be willing to introduce *Bt* genes into locally adapted African varieties, but obviously, in that case, the yield potential would be similar to that of the African parent. Any yield gains from the adoption of *Bt* cotton will be the result of improved pest management and will require best agronomic practice to obtain a yield gain sufficient to cover the additional input cost contributed by the *Bt* technology fee.

Under the sort of pest pressure that requires the use of insecticide sprays to control bollworms (particularly *Helicoverpa armigera*), the farmer may benefit from growing a *Bt* variety due to the potential for obtaining the same yield as with the non-*Bt* variety, but with fewer sprays. The issue then becomes one of cost/benefit, that is, is the pest pressure and the number of sprays being done

sufficiently high that the savings from growing a *Bt* variety more than cover the higher seed cost? Of course, there would be health and environmental benefits from decreased pesticide use, which cannot be measured in terms of economics.

One might suppose that as *Bt* cotton varieties have been grown in several countries for a decade or more, there would be plenty of evidence on which to judge their success. Unfortunately this is not the case. Much of the opinion is polarized, with the seed companies and organizations with a mission to promote biotechnology emphasizing the benefits, while the other side is represented mainly by organizations ideologically opposed to genetic engineering. Many of the favourable independent studies were based on field trials, questionnaire surveys and/or were conducted before problems associated with longer-term planting of *Bt* cotton developed. Furthermore, conclusions drawn from outside the region may not be applicable to the smallholder sector in SSA. Even in RSA, where much publicity has been given to the adoption of *Bt* cotton by the smallholders on the Makhathini Flats, their cotton fields are on average larger than in most of the rest of SSA and their use of insecticide is probably more intensive. In any case, at the time that *Bt* was introduced, at least 90% of South Africa's cotton crop was produced by the large-scale sector.

In both India and parts of China where cotton is largely a smallholder crop, insecticide spraying had become intensive and the number of sprays escalated as populations of the main target pest, *Helicoverpa* bollworm, became increasingly insecticide-resistant. Resistance to organophosphate and pyrethroid insecticides has been reported from West Africa (Thibaud *et al*, 2000, 2005) and may have been a risk among large-scale growers in RSA, but with the exception of Sudan where cotton in the Gezira was subject to intensive spraying, I am not aware of reports of insecticide resistance in smallholder cotton from elsewhere in eastern and southern Africa.

Can lessons be learned from experiences elsewhere?

South Africa

In South Africa in 2001, 95% of the cotton crop was produced by 300 large-scale farmers and the rest by more than 3,000 smallholders. *Bt* cotton has been grown in South Africa since 1997/98, and by 2000, it was estimated that 75% of smallholders were growing the *Bt* variety (Gouse *et al*, 2003). At first, most of the peer-reviewed reports about *Bt* cotton adoption by smallholders in Makhathini were favourable and have been used to promote the technology in the rest of Africa. When cotton smallholders there began to experience economic losses, it was explained that this was due to a combination of consecutive seasons of drought affecting Kwazulu-Natal and a change in the marketing arrangements. When *Bt* cotton was first introduced, the Makhathini smallholders were served by a single ginnery and this monopoly position gave the ginning company the confidence to invest in a credit scheme that allowed farmers to cover the input costs and technology fee for the *Bt* variety. When a

second ginnery was licensed to operate in the same area, competition for seed cotton became the priority and the number of loan defaulters rose dramatically, leading to the collapse of the input credit system (Fok *et al*, 2007). Without access to credit, the technology fee for the *Bt* variety became unaffordable for many cotton farmers at Makhathini. By 2002/03, the number of cotton smallholders had fallen to 400, although promotion of irrigation by the new ginning company has seen numbers rise again (Fok *et al*, 2007). The conclusion drawn by one study was that the introduction of *Bt* cotton for smallholders in RSA had been a 'technical triumph but an institutional failure' (Gouse *et al*, 2005).

Two lessons can be learned from the experience in RSA. First, in seasons when weather conditions are unfavourable for cotton production and in the absence of irrigation, smallholder profits from cotton are unlikely to be sufficient to cover the input costs and technology fee. Second, the role of the ginnery is crucial in providing input credit and ideally, technical support services.

China

Bt cotton varieties were released commercially in China in 1997 and were rapidly adopted. By 2007, 3.8 million ha of GM cotton were being grown by 7 million households, representing more than two-thirds of national production (James, 2007). Average cotton holdings are small in China, at only 0.59 ha per household. This is similar to individual holdings in many SSA countries, but in some provinces of China, such as Xinjiang, a number of farmers may grow their cotton in a block.

Most of the adoption studies of *Bt* cotton in China concluded that *Helicoverpa* was well controlled, at least in the early part of the season, resulting in a decreased requirement for insecticide and cost savings (for example, Huang *et al*, 2003). The main risk identified has been an increase in secondary pests such as thrips, aphids, whitefly, spider mites, lygus bugs and leafhoppers, which have occasionally replaced bollworm as the primary pest (Xue, 2002). In some parts of China, this risk appears to have become a reality. During the first three years of planting *Bt* cotton, pesticide use was cut by more than 70% and profits were higher than those obtained by farmers growing conventional cotton varieties. However, by 2004, due to continued increases in populations of some sucking pests on *Bt* cottons, spray frequency had returned to the levels used previously on conventional cotton, resulting in lower profits for the *Bt* cotton farmers (Cornell, 2006; Wang *et al*, 2008). These problems have arisen because *Bt* cotton is not being deployed as an integrated pest management (IPM) component technology and adoption has not been accompanied by adequate technical support services. A study conducted in northern China, for instance, found that farmers were still spraying more than was necessary to control sucking pests and they had a poor understanding of pest identification and management (Yang *et al*, 2005a). Where *Bt* cotton has been deployed within an IPM framework, less pesticide is used and higher profits obtained and the key to success has been access by cotton farmers to IPM education (Yang *et al*, 2005b).

Chinese experience provides lessons for Africa. Where regular spraying has previously been carried out,

primarily for bollworm control, if farmers adopt *Bt* varieties and cease to spray, minor or secondary pests may become more of a problem. For example, results from China show that the populations of lygus bug can increase greatly on unsprayed *Bt* cotton. Lygus bug (*Taylorilygus vosseleri*) is a significant pest on cotton in Uganda, but is kept in check by sprays targeted at bollworms. This has also been the case in China with leafhoppers, similar to the cotton jassid bug, which is potentially a major pest of cotton in eastern and southern Africa.

The commitment has been poor at all levels in most SSA countries to the implementation of IPM, and the failure to promote scouting-based pest management systems in the smallholder sector may have repercussions when *Bt* varieties are adopted. Regular scouting to detect when populations of sucking pests are increasing towards their damage thresholds is a necessary component of improved integrated crop management (ICM) systems that will be required to profit from costly *Bt* technology. This implies the need for greater investment in technical support services by the private and/or public sectors.

India

Bt cotton was introduced into India only in 2002, but by 2007, *Bt* varieties were being grown by 3.8 million smallholders, covering 6.2 million ha (James, 2007). The average cotton holding is larger than in China, at 1.63 ha per household.

As in China, most of the independent reports on *Bt* adoption across India have been favourable. For instance, Morse *et al* (2007) reported that gross margins among farmers who had adopted *Bt* cotton were 2.5 times higher than among non-adopters, but they acknowledged that results might be influenced as much by differences between adopters and non-adopters as by the technology. A nationwide survey conducted in 2003 concluded that yield increase associated with *Bt* adoption was 29%, with a 60% decrease in insecticide use and a 78% increase in net profit (Ahuja, 2007).

A large number of Indian seed companies have produced or are developing their own *Bt* cotton varieties, in addition to the Monsanto varieties. There is therefore a wide range of quality and performance. Wide publicity was given to cases in which the adoption of *Bt* cotton failed to provide an economic benefit (for example, Quayum and Sakhari, 2004), but it seems that in most cases, these failures were explained by one or a combination of poor seed quality, drought and poorly performing genetic background used for the transformation (Ahuja, 2007; Bennett *et al*, 2006).

Indian cotton does not seem to have suffered to the same extent as China with the problem of an upsurge in secondary pests associated with decreased insecticide use on *Bt* cotton. Such reports from India are anecdotal and not supported by scientific data. The Grain (2007) Website carried a report of a new mealy bug pest and other pests and diseases affecting *Bt* cotton in the Punjab. Another report (InfoChange, 2007) mentioned that in Andhra Pradesh, attacks by aphids, thrips and jassids had increased since the introduction of *Bt* cotton in 2002. It is possible that scientific studies that support these news stories have yet to be published and that the lack of

reports of secondary pest resurgence in India simply reflects the later introduction of *Bt* cotton into India, as compared with China.

The main lesson from India is that the adoption of *Bt* cotton can have large economic benefits where there is high pest pressure from *Helicoverpa* bollworm and spray frequency has escalated in response to insecticide resistance. The qualifier is that the seed quality and agronomic performance of the adopted *Bt* variety must be at least as good as the non-*Bt* variety it replaces. Nowhere in SSA is there such a combination of high bollworm pressure and pesticide resistance as was the case in several Indian states before the introduction of *Bt* cotton. Expectations in Africa of economic benefits from the adoption of *Bt* cotton should be adjusted accordingly.

Conclusions

Bt cotton must be treated as a crop protection technology and, in common with other insect management technologies, should be deployed within an IPM/ICM framework. Ideally, *Bt* cotton should be introduced into a country after IPM has been adopted by cotton smallholders. In practice, *Bt* cotton is being mistakenly promoted as an alternative to IPM. The main reason for this is that IPM is a 'knowledge-intensive' technology and the cost and manpower required to deliver the necessary technical support to farmers through public sector institutions has proved prohibitive. While it remains debatable whether or not it is possible to implement scouting-based IPM in SSA, the evidence from China is that IPM adoption can deliver the same results in terms of decreased pesticide use and increased profit margins as can be achieved by adoption of *Bt* cotton varieties (Yang *et al.*, 2005b).

At current average yields, GM cotton is an unaffordable technology for smallholders in most SSA countries in eastern and southern Africa. The better farmers who manage the crop well and obtain higher than average yields will be able to benefit, but the priority for the others is for the ginners to provide input credit and technical advice to improve crop husbandry standards. The more vertically integrated cotton sectors in Francophone West Africa, with higher yields, may benefit from *Bt* technology, provided credit schemes and technical support systems are sustained.

Bt cotton should be promoted as a crop protection technology and as a component of an IPM system. Should it prove necessary to carry out one or more sprays against bollworms or sucking pests on *Bt* cottons, regular scouting will be essential to optimize spray timing. If farmers believe that they can forget about pest management now that they have a *Bt* variety, unexpected insect attack may erode their already fragile profit margins.

Ginning companies should not expect the introduction of *Bt* cotton to result directly in increased production. The benefit is through a decrease in insecticide spraying, which may improve the profitability of cotton growing for those who presently use at least 4–6 sprays. The possibility of growing cotton without the need for insecticide may encourage more people to grow the crop, but it will prove difficult for them to recover the

additional seed cost, unless they follow basic recommendations for plant spacing, planting date, timely thinning and weeding. The removal of bollworm damage as a yield-decreasing factor may increase the number of farmers who can benefit from fertilizer application because of the strong interaction between the effect on yield of fertilizer application and insect control.

An important reason why so many cotton smallholders in SSA do not follow best practice in cotton crop management is labour shortage, mainly for thinning and weeding. Either there is insufficient family labour, or additional employed labour is unaffordable, at a time when the need for labour in cotton fields coincides with demand for labour to tend the staple food crops. As weeding is the most labour-demanding activity on African smallholdings, it could be argued that Roundup-ready (RR) cotton would be a more appropriate first step into GM crops than *Bt* cotton. It is more economical to use herbicide for weed management than to rely exclusively on human labour, especially in areas where animal draught power is available and reduced tillage can be implemented. However, the constraints are the lack of knowledge on herbicide use/conservation tillage technology and opposition to increased pesticide use. When African governments enter into agreements with biotech companies to transform locally adapted cotton varieties, they should argue for the acquisition of 'stacked' genes – two *Bt* proteins, which extend the period of effectiveness of *Bt* toxin expression in the cotton plant, together with RR technology.

Requirements for successful adoption of GM cotton technology in SSA

The following requirements are suggested for successful adoption:

- (1) A well implemented public information campaign will be needed so that the potential benefits of *Bt* cotton are understood and farmers come to appreciate that making a profit will depend, even more than it did with conventional varieties, on the implementation of best practice in integrated crop management (ICM).
- (2) Farmers should have access to credit for input purchase and should be well supported with technical advice. The public sector extension service does not have the manpower to deliver this and the appropriate provider is the ginning company. The conflict between cooperation and competition between ginning companies will need to be addressed in some countries.
- (3) Well before the commercial release of GM varieties, plans need to be in place for seed multiplication and seed separation. Not all farmers will have the technical competence to benefit from *Bt* technology, and non-*Bt* varieties will therefore have to remain available to them. However, this will create a problem of how to keep the *Bt* and non-*Bt* varieties separate. There is a similar issue with organically and conventionally grown cotton.
- (4) It must be ensured that the period of validation of *Bt* technology – confined field trials and open field trials

- is overseen by organizations without a vested interest in the adoption of GM technology.
- (5) *Bt* cotton should be promoted as an IPM component technology, not primarily as a yield-enhancing one.

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